Assignment 4

1 Design Exercises

1.1 (5 points)

Design a high-pass RC filter that can filter out 60 Hz and 120 Hz but yet still pass signals above 10 kHz (G $\geq$ 0.8 for frequencies $\geq$ 10 kHz). This filter should work with a load of at least 100 kΩ. You can assume that your signal source has a 50 Ω impedance or lower. Make the Bode plot of the amplitude transfer function G. For this plot, show the magnitude of the transfer function, |G|, of this filter in dB, mark the -3dB point. What is the phase value, when $|G| = -3$dB.

1.2 (2 points)

The main characteristic of a filter is the signal to noise ratio (SNR) improvement, which is defined as the ratio of gains (transfers) for "bad" and "good" frequencies: $|G(f_{good})|/|G(f_{bad})|$. In the above design, what is your filter SNR improvement, if $f_{good} = 10$kHz and $f_{bad} = 100$Hz.

1.3 (5 points)

Design a band-pass filter which will only pass frequencies near 10 kHz (|G(10 kHz)| $>$ 0.80) and filter frequencies below 1kHz and above 100kHz. This filter should work with a load of at least 100 kΩ. You can do this by combining 2 different RC filters (one high-pass and one low-pass). You can assume that your signal source has a 50 Ω impedance or lower. Make the Bode plot of the transfer function of this filter magnitude (in dB) and phase. Mark the -3dB points.

1.4 (8 points) (Can be done after the lab)

What is the maximum achievable SNR improvement for the high-pass filter? Name two relevant frequencies f_{good} and f_{bad}. Hint: such filter has a gain at good frequency, $G(f_{good})$, significantly less than 1. Note: the maximum SNR improvement is the same for low-pass filter.

2 Lab 4: AC signals and filters

Always start with a circuit diagram and only then build it in hardware.

Your notebooks must be complete, understandable, and address all activities, design exercises, observations, and questions noted in the laboratory's procedures. Remember to use your notebook as a laboratory journal and record your data, design calculations, notes and scratch work. *Make sure to write a conclusion for each exercise and each week.*

Task 0

Demand

- a review of oscilloscope probe's 1 and 1/10 settings.
- a tutorial on use of TTL/Pulse channel for a function generator hooked to an oscilloscope.

2.1 Task 1 (5 points){-} (Play around, learn the tools, nothing quantitative here)

Set a function generator to output any signal with frequency of about 2 kHz. Connect TTL/Pulse output to a scope (I suggest to use ch4) and use it as a trigger. Connect the functional output to another input (I suggest to use ch1). Observe that the oscilloscope stays triggered with any variation of the functional output.

Task 2 (20 points), Duration: 1 hour

Set function generator to output **square** wave with about 2 V_{pp} amplitude, do your best to null the offset, i.e. your signal should be symmetric with respect to a zero volts line. What type of coupling should you use for the scope input to monitor the function generator output? Why?

Grab a resistor of about 2 kΩ and a capacitor in the range of 100 nF to 1 μF connect them in series (i.e. make a voltage divider) and connect it to the function generator.

You goal is to see the voltage signal across the capacitor (V_C). **Function generators and oscilloscopes have their references (outer shield) connected to the ground and thus to each other even if they are not in a visible direct contact**. Think how you should connect them. Call instructor to confirm you idea. **Do not power the function generator without an instructor confirmation**.

It is good idea to use another channel of the scope to directly observe the function generator output. Set frequency to something like 10 Hz. Observe and sketch shape of the signals from the function generator and V_C. Now sweep frequency to higher values (10kHz and more).

How does the signal look at the higher frequency? What can you say about V_C amplitude, is it increasing or decreasing? Make a plot of the signal amplitude versus frequency.

What can you say about shape of the signal and its frequency with respect to 3dB point.

Task 3 (25 points), High-Pass Filter, Duration: 1 hour

Design and construct a high-pass RC filter that can filter out 60 Hz but still pass signals in the 10 kHz region. The one from design exercises is a good one to start. Measure the bode plot of your filter (magnitude and phase).

Connect a 10 kΩ load to your filter, remeasure the bode plot. Did it change significantly? Why so?